Metabolism

Lecture 3

Heat production regulation & mechanism of fever

ILOs

- By the end of this lecture the student will be able to:
- Describe the mechanisms by which heat is produced in and lost from the body
- List the body temperature that is recorded from rectum, oral cavity, and skin
- Explain the mechanisms by which the body temperature is regulated
- Explain the pathophysiology of fever

The body can be divided into two regions:-

a- The Core (contents of the skull, thorax & abdomen).

b- The shell (includes the skin, subcutaneous tissues & the limbs).

* Core temp. is relatively constant.
* Shell temp. is variable according to the environmental conditions.

Normal Body Temp.

The normal body temperature is different from individual to individual, the average in young adult:-

Orally: - 36.3°C: 37.1°C (97.3–98.8 °F). It can be affected by: Food ingestion, gum chewing, and mouth breathing.

Rectally: - ≈ 0.5°C more than oral temp.

N.B.:

* The rectal temperature is representative of the temperature at the core of the body and varies least with changes in environmental temperature.
* The temperature of various parts of the body are different, its magnitude varies with the environmental temperature.
* The extremities are generally cooler than the rest of the body.
* The temperature of the scrotum is carefully regulated at 32 °C.

Sites of measurement of body temp.:- Mouth, rectum, axilla, skin, ……..

Variation in body temp.:-

1- Diurnal rhythm: circadian fluctuation. (It is lowest in the early morning & rises to maximum in the early evening due to changes in MR).

2- Sever exercise: During exercise, the heat produced by muscular contraction accumulates in the body and the rectal temperature normally rises as high as 40 °C (104 °F), due in part to the inability of the heat-dissipating mechanisms to handle the greatly increased amount of heat produced.

3- Sex: In females the body temp. rises by 0.5 in the second half of menstrual period due to thermo genic effect of progesterone .

4 - Emotions: increase body temp. due to sympathetic activity & unconscious tensing of the muscles.

5- Age: Temperature regulation is less precise in young children and they may normally have a temperature that is 0.5 ° or so above the established norm for adults.

6- Individual variation: Some persons have temp. higher than the normal range (constitutional hyperthermia).

7- Endocrine factor: It is chronically elevated ≈0.5 °C when the metabolic rate is increased, e.g. hyperthyroidism, and lowered when the metabolic rate is low, as in hypothyroidism.

8- Environmental temp.: Body temp. increases in hot weather and decreases in cold.

Heat Balance

Heat gain = Heat loss

WHY ???? Because the balance between heat production and heat loss determines the body temperature, that must be relatively constant for normal body functions

WHY ??? Because the temperature alters the speed of chemical reactions since the body's enzyme systems have optimum temperature for function.

SO, a group of reflex responses that are primarily integrated in the hypothalamus, operate to maintain body temperature

within a narrow range in spite of wide fluctuations in environmental temperature.

Heat Balance

The main factors that lead to heat production (gain) are:

1- Muscular exercise.

2- All the vital processes that contribute to the basal metabolic rate.

3 - Endocrine factors like:-

* Thyroxin (slow prolonged effect).

* Epinephrine and norepinephrine (rapid and short effect).

4- External environment: sun rays (↑ temp. leads to increase of chemical activity of all cells).

5- Food intake: Assimilation of food (SDA thermal effect of food).

6- Brown fat: Special type of fat only in infants with high rate of metabolism and richly supplied by sympathetic nervous system.

Ways of heat loss

1- Conduction: It is the transfer of heat between objects of different degrees of temp. that are in direct contact with each other. Heat moves down its thermal gradient from warmer to cooler objects.

N.B.: Conduction is greater in presence of air currents and greatest in the presence of water.

2- Convection: is the transfer of heat through currents of air.

It greatly aids heat loss via conduction by exchanging warmer air at the surface of the body with cooler air in the surrounding space.

N.B.: If the temperature of air adjacent to the skin rises and becomes equal to skin temperature it forms an insulator zone preventing further heat loss.

Convection occurs passively as warmer air at the surface of the body rises away from the body and is replaced by cooler air, but the process may be aided by fans or wind.

3- Radiation: Transfer of heat from hot body in the form of electromagnetic waves. e.g. the sun warms the earth by radiation.

N.B.: Environmental temp. must be less than body to have heat loss by radiation.

The greater the thermal gradient the more will be the amount of radiation.

4- Evaporation: Evaporation of one ml of water causes loss of 0.6 ˚C.

Evaporation Increased with sweating & convection and decreased with humidity of weather.

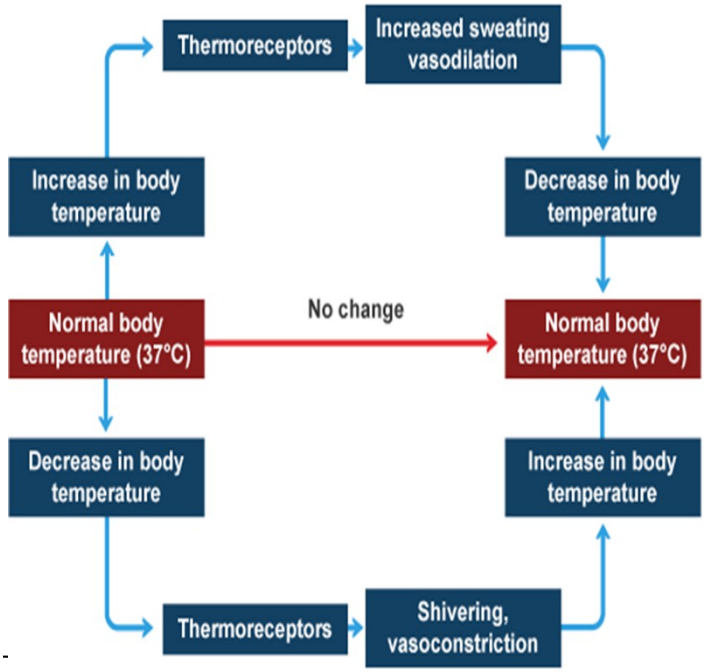
In comfortable zone (24: 34°C) temperature, 70% of heat loss occurs through radiation, conduction, convection and 30 % occurs through evaporation.

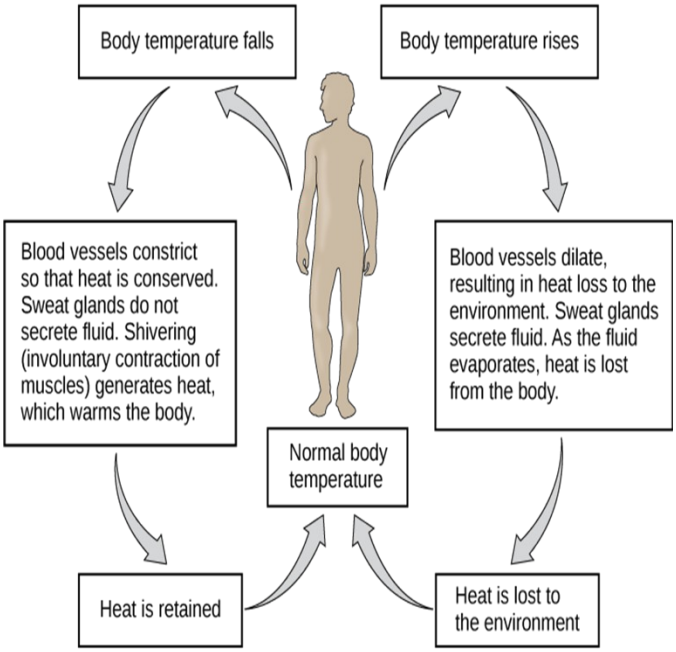
So, the heat is lost from the body by: Radiation, conduction, and vaporization of water in the respiratory passages and on the skin. Small amounts of heat are also removed in the urine and feces.

If the surrounding temp. is greater than that of the skin, sweating will be the only mechanism for heat loss.

The relative contribution of each of the processes that transfer heat away from the body varies with the environmental temperature. At 21 °C, vaporization is a minor component in humans at rest. As the environmental temperature approaches body temperature, radiation losses decline and vaporization losses increase.

Body temp. regulation

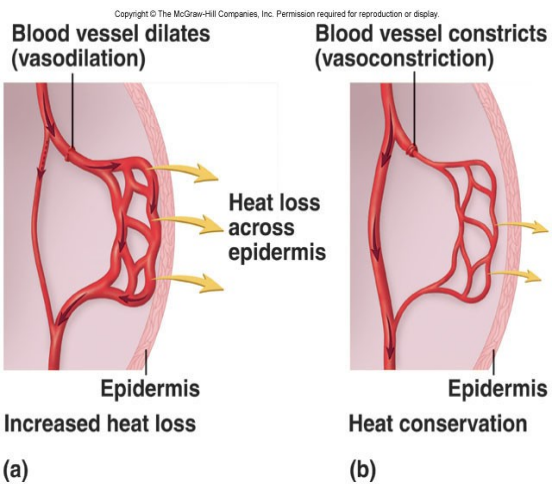




Heat Loss

* Most of heat production in the body is libe

the deep organs (liver, brain, heart,…. & sk



during exercise).

* Heat is lost from deep tissues to the skin & then to

air via blood flow.

- The skin & subcutaneous tissues act as insulator system that conduct only 1/3 of heat production to keep body temp. in their physiological range.

*** **Water evaporation from body occurs in two forms:-**

Insensible perspiration: - From the skin and lungs ≈ 50 mL/h in humans.

Sweating: - From sweat glands. Regulated by SNS.

Humidity 1/α sweat evaporation (↓sweat secretion).

Sweating

Def.: Homeostatic method by which heat loss is increased via the skin by evaporation.

Mechanism of sweat secretion: - Sweat sec. center is located in the ant. Hypothalamus which sends signals to eccrine sweat glands via *sympathetic cholinergic fibers*→ sweating.

Primary secretion: Takes place from the deep subdermal secretory portion of the sweat gland. The secretion contains (water, Na+, cl-, K+, urea, lactic acid) i.e. is similar to plasma except plasma proteins.

Secondary secretion: It takes place by the duct. It is a modified primary secretion mainly by reabsorption of Na^+ and H_2O. Its concentration depends on the rate of sweating.

N.B.:

* Sweat secretion occurs when the non-evaporative heat loss mechanisms fails to maintain body temperature constant. So it starts when the environmental temperature exceeds 32-34°C and also when the heat production in the body is more than the capacity of these mechanisms to get rid of excess heat.
* During exercise and fever sweating occurs *inspite* of the atmospheric temperature is below 0°C.
* Panting which is an increased resp. or rapid shallow resp. occurs in animals having no sweat glands like dogs, cats & rabbits.

Types of sweat glands:

a- Eccrine:- It regulates body temp. via evaporation& stimulated by…???

b- Apocrine:- It presents in certain locations & stimulated by *symp. adrenergic fibers* under emotional conditions.

N.B.: Excessive sweating → Dehydration, loss of electrolytes → Ms. cramps.

May leads to heat exhaustion. ??

Acclimatization of sweat secretion:

When the person is exposed to hot weather for 1-6 weeks his sweat secretion markedly affected by increase in its volume up to 2 L/hour (normally 700 ml/h) with decrease

concentration of NaCl (3-5 g) (normally up to 15-30 g) by the **aldosterone hormone.**

Temperature regulating centers = hypothalamic thermostat

The hypothalamus is said to **integrate** body temperature information from sensory receptors (primarily cold receptors) from the following five inputs, each contributes about 20 % of the information that is integrated.

**The skin,* *Deep tissues,* *Spinal cord,* *Extrahypothalamic portions of the brain & *The hypothalamus* itself.

Temperature regulating centers

- Heat loss center, Site: Anterior hypothalamus.
- Heat gain center, Site: Posterior hypothalamus.

These centers detect variation of body temperature from the set point and they discharge impulses to the effector organs to modify rate of heat production or loss.

Set point is a standard critical temperature, when body core temperature either increases or decreases above or below it, several thermoregulatory mechanisms takes place to bring it back to this temperature.

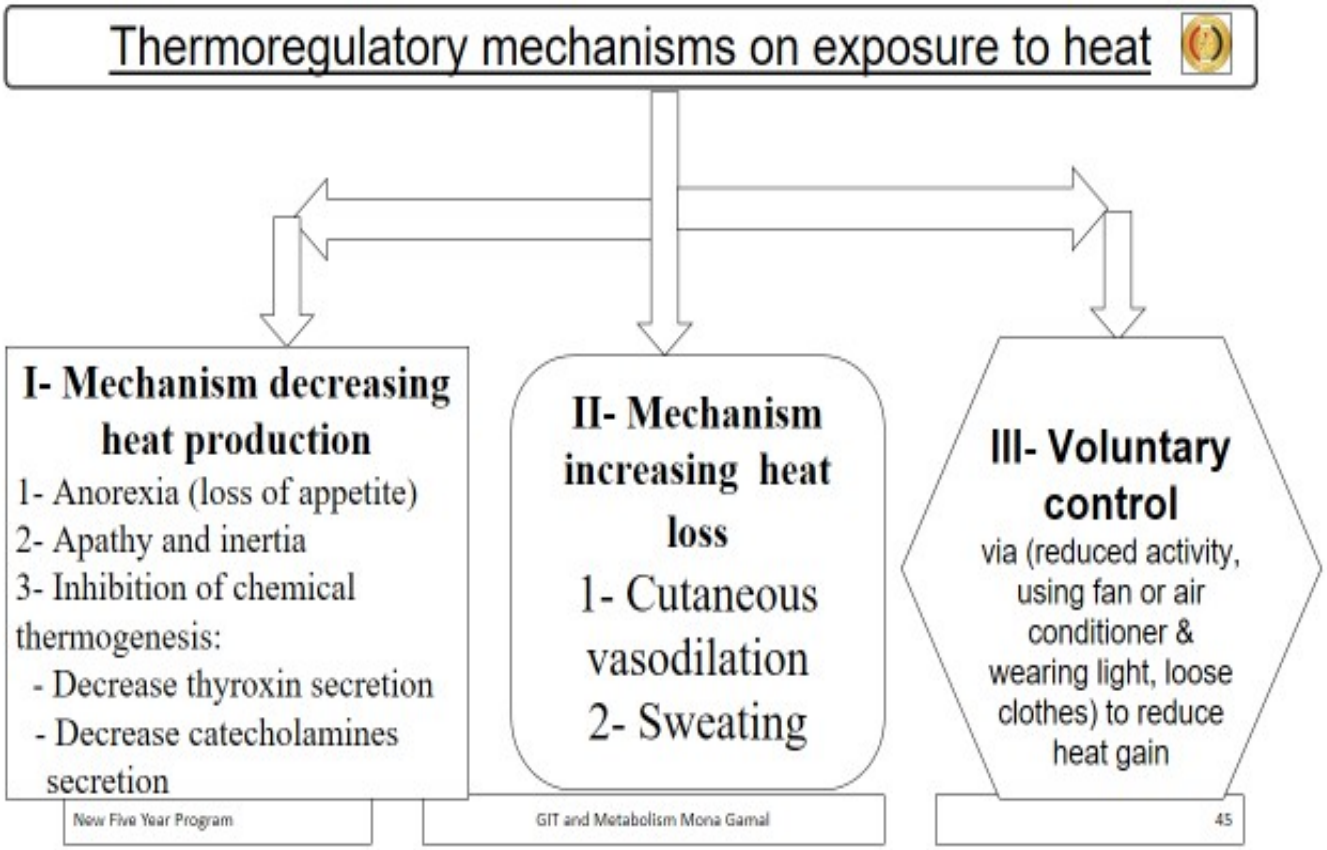
*** There are ***threshold core temperatures for each of the main temperature-regulating responses*** and when the threshold is reached the response begins. The threshold is *37 °C*

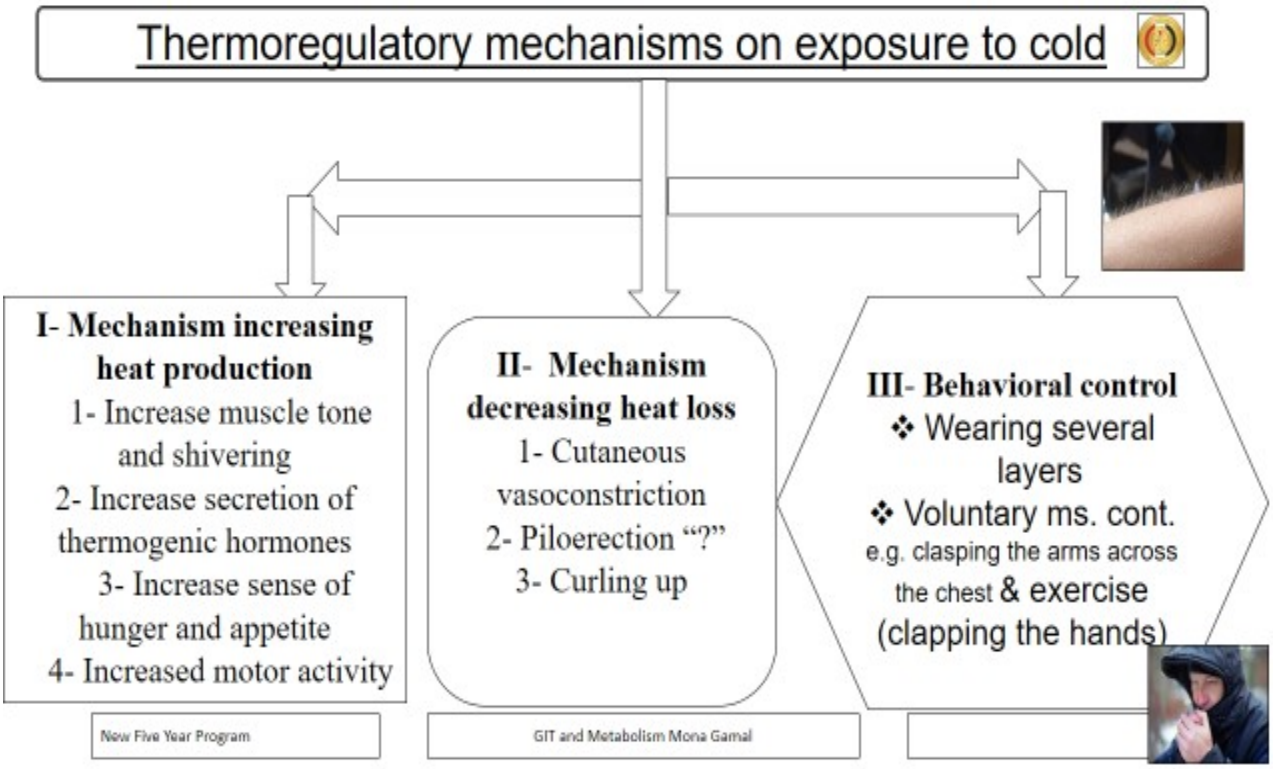
for sweating and vasodilation, *36.8 °C for vasoconstriction*, *36 °C for nonshivering thermogenesis*, and *35.5 °C for shivering*.

Thermoreceptors: They are receptors that detect changes in temperature → discharge to the hypothalamic control centers.

Peripheral thermoreceptors, Site: Skin, spinal cord, abdominal viscera and around great veins. They monitor skin temperature, warmth and cold receptors, they are concerned mainly with detection of cold. So, regulatory mechanisms against cold are due to stimulation of both central and peripheral thermoreceptors while those against heat are due to stimulation of the central thermoreceptors mainly.

Central thermoreceptors: Site: in preoptic area of the anterior hypothalamus, monitor head (local) temperature, includes heat and cold sensitive cells.


Thermoregulatory mechanisms on exposure to heat
I- Mechanism decreasing heat production
1- Anorexia (loss of appetite)
2- Apathy and inertia
3- Inhibition of chemical thermogenesis:
- Decrease thyroxin secretion
- Decrease catecholamines secretion
II- Mechanism increasing heat loss
1- Cutaneous vasodilation
2- Sweating
III- Voluntary control
via (reduced activity, using fan or air conditioner & wearing light, loose clothes) to reduce heat gain
New Five Year Program
GIT and Metabolism Mona Gamal
45



Abnormal body temp.

Hyperthermia (heat stroke): It is an elevation of body temperature higher than the thermoregulatory set point (usually above 41○C).

Sun stroke: It is a sever condition of heat stroke due to prolonged exposure to solar sun rays.

Fever: It means elevation of the core body temperature above the level which is normally maintained by the individual.

Hypothermia: is defined as a core temperature (less than 35°C.

Frost bites, when the body is exposed to an extremely low temperature, the surface area can freeze, this freezing is called frostbite.

Fever (Pyrexia)

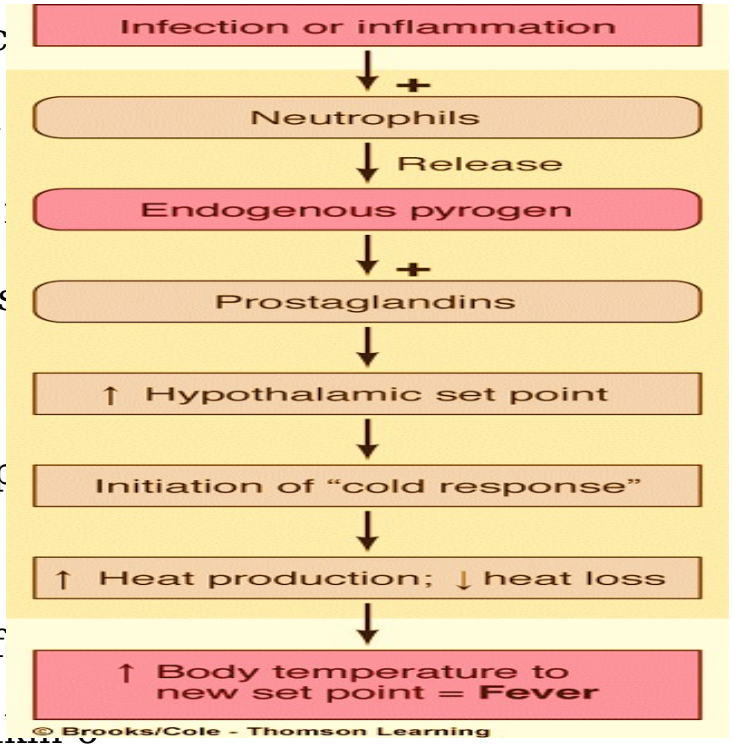
It means elevation of the core body temperature above the level which is normally maintained by the individual. So, the thermoregulatory mechanisms behave as if they were adjusted to maintain body temperature at a higher than normal level, “as if the thermostat had been reset” to a new point above 37 °C”.

*So, all the mechanisms for raising the body temperature are activated e.g shivering, vasoconstric

*Body temperature rarely exceeds 4

*It commonly results from bacterial

*It also results from certain brain les



Pathogenesis: (Mechanism):→

Substances which elevate body temp

(=pyrogens) act on immune system

(Monocytes, macrophages and kupff

→ Produce cytokines such as interlu

(IL-6), Tumor necrosis factor (TNF-α), interleukin-1 (IL-1β) & interferons (β-IFN, γ-IFN).

- ❖ Cytokines are also produced by cells in the central nervous system (CNS) when these are stimulated by infection, and these may act directly on the thermoregulatory centers.

*These pyrogens activate preoptic areas through local release of prostaglandins.

*Substances (Drugs) which decrease fever are anti prostaglandins.

Significance of fever:-

1- It directly inhibits the growth of many microorganisms.

2- Interleukin-1 increases formation of neutrophils in the bone marrow that attack microorganisms. It also stim. Lymphocytes to increase production of antibodies increases immunity.

3- It slows the growth of some tumors.

N.B.: Temp. above 43 ˚C causes heat stroke & death due to permanent brain damage.

SUGGESTED TEXTBOOKS

1. Ganong's "Review of Medical Physiology", 25th edition, chapter 17, Section III, pages 319-320
2. Guyton and Hall "Textbook of Medical Physiology", 12th edition, chapter 72, pages 867-880

3. Sembulingam "Essentials of Medical Physiology", 6th edition, chapter 63, Section 5, pages 359-364 & Chapter 130, pages 746-748